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Chapter 4
Lower limbs. Ontogenesis, anatomy, deformations

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4.1. Ontogenetic development of lower limbs in children

In the initial stage of ontogenesis, human lower limbs undergo many changes. In the prenatal period, the limb buds develop beginning from the 3rd week after fertilisation.[1] The 6-week-old embryo already has foot plates that over time are divided into 3 segments. Around the 7th week of embryonic development, primary ossification centres are observed, and the buds of the lower limbs already reach ¼ of the length of the trunk and head.

In the first stage of the postnatal life, complete flexion of the lower limbs is observed, which is a remnant of intrauterine development. This phenomenon persists until about 1–1.5 months of age. Taking into account the growth rate of the lower limbs, the feet dominate until the age of 3. Developmental changes, however, also occur at the level of knee and hip joints and undoubtedly affect the way the foot is positioned in the later period of ontogenesis.

The infant's foot has not yet longitudinal arch, and its plantar part is filled with a soft cushion made of adipose tissue and connective tissue. The role of the fat pad

1 J. Walocha, A. Skawina, J. Gorczyca, (2006), *Anatomia prawidłowa człowieka. Miednica. Podręcznik dla studentów i lekarzy. Wydanie II poprawione*, Wydawnictwo Uniwersytetu Jagiellońskiego, Kraków, pp. 13–19.

is to absorb the shocks caused by the foot hitting the ground. This is especially important in the course of learning to walk, during which the child puts his feet flat and no propulsion is observed.

At this stage of ontogenetic development, ossification of the foot is still poorly advanced. The entire vault of the foot undergoes alterations (both longitudinal and transverse arches), and in children we observe physiological flat feet, which disappear around the age of 6–7 (girls achieve it faster than boys). According to the related literature, the foot of a 10-year-old child is already arched in the same way as the foot of an adult.[2]

Beneath there are scans of the foot of a child aged 2 and 8 years. There are clear differences in the morphology of the foot and the proportions of respective sections of the foot.

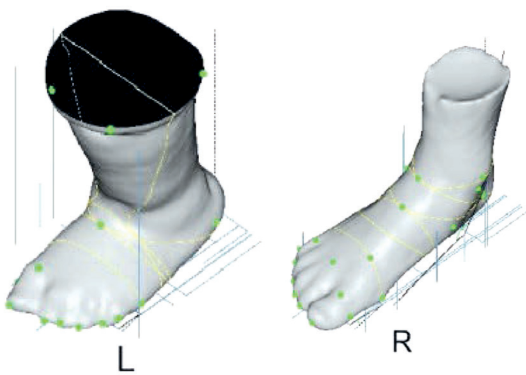

Figure 4.1. 3D scan of the foot of a 2- and 8-year-old boy
Source: own elaboration.

In the related literature, the construct of the "golden age of mobility" can be found. This is a period of particularly dynamic changes in the development of the lower limbs, occurring around 4–5 years of age. It is estimated that at this time the length of the lower limbs exceeds a half of the length of the body.[3]

During the puberty spurt, there is a significant acceleration of foot growth in length. However, the skeletal system grows faster than the muscular system, which is often the cause of foot fatigue at that age and the lowering of the longitudinal arch of the foot again (the muscular system does not keep up with the growing skeletal system). Thus, it is important to maintain the proper function of muscles and control their efficiency.[4]

2 N. Wolański, (2005), *Rozwój biologiczny człowieka*, Wydawnictwo PWN, Warszawa, p. 125.

3 N. Wolański, (2005), *Rozwój biologiczny…*

4 A. Zalewska, K. Średzińska, W. Kułak, (2021), *Postawa ciała a siła mięśniowa u dzieci w wieku szkolnym*, Uniwersytet Medyczny w Białymstoku, Białystok, p. 19.

The formation and development of the foot must be considered strictly in terms of the development of the entire musculoskeletal system. The position of the feet and the arrangement of their long axes in relation to one another, the position of the tarsus closely correlate with the position of the more proximal sections of the lower limb: the knee joint and the hip joint.

During ontogenesis, the position of the axes of the lower limbs also changes. The initial varus position of the knees resulting from the position of the lower limbs in intrauterine development transforms into the valgus position, which disappears around the age of 6–7. It needs to be stressed that we are describing the phenomenon of physiological varus and valgus of the knees.

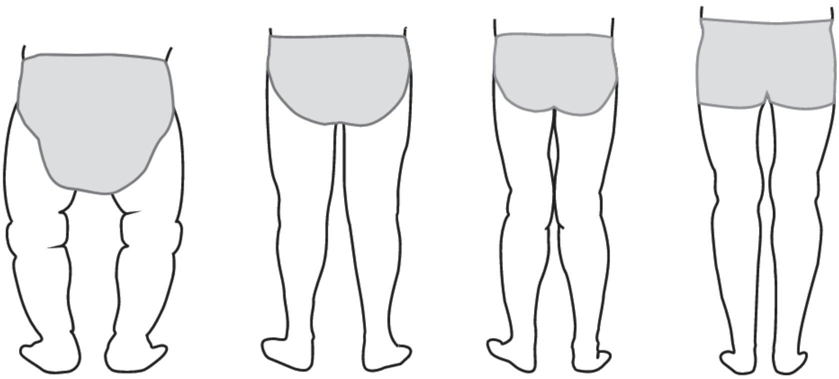

Figure 4.2. Changes in the position of the knees in the process of ontogenesis
Author: Tetiana Paruzel.

4.2. Children's feet deformations

Deformities and other foot ailments are associated with changes in the shape and impairment of the foot function, which have their source in abnormalities of soft tissues or bone tissue.

The moment of formation of foot defects gives rise to the basic classification of them. Foot defects can therefore be divided into congenital and acquired ones.

Lower limb deformities are common pathologies that significantly worsen body statics and lead to posture defects. They are birth defects or develop as a result of deformations of higher parts of the body, or various types of overloads.

The musculoskeletal system is often affected by congenital defects. The causes of developmental distortions can be endogenous and exogenous. Endogenous factors are mainly gene mutations or chromosomal aberrations. Most of the musculoskeletal system diseases (dysplasia, dystrophy, dysostosis) have a genetic background. They are inherited in an autosomal dominant, autosomal recessive or polygenic manner.[5] Exogenous factors may include: fetal hypoxia, taking medications during pregnancy, maternal diabetes, dietary deficits, ionizing radiation, disease during pregnancy. In recent years, a large role has also been attributed to mechanical factors (oligohydramnios, stronger uterine muscles in primiparous women causing pressure on the hip joints) and the hormonal changes during pregnancy - especially in the last 3 months (increased secretion of oestrogen and relaxin). Significant developmental abnormalities of all organs may develop up to the 3rd month of pregnancy. After this period, the foetus is already a fully formed human. Significant distortions are also called congenital teratological defects and arise during organogenesis, i.e. the formation of organs, and those are the so-called malformations. In turn, fetopathies are developmental disorders that develop in a genetically normal embryo only after the embryonic period (i.e. after the third month of pregnancy when organogenesis is already completed).[6, 7]

The most common birth defects of the feet in children include:

- club foot,
- adducted foot,
- congenital flat – valgus foot,
- heel foot,
- congenital hyperextension of the knee joint,
- congenital tarsal bone coalitions,
- extra navicular bone,
- syndactyly and polydactyly,
- fingers curled and overlapping.

Acquired defects arise in the postnatal stage of ontogenesis. An early start to walking may cause disorders in the proper development of the foot and the whole legs, and thus also the body posture.[8] The most common cause of acquired defects includes mechanical injuries caused by both incorrectly selected footwear and traumatic damage to the musculoskeletal system (fractures, sprains, dislocations).

One of the factors blamed for development of deformations is incorrect footwear. It is comparatively new acquisition in our phylogenesis. Footwear is designed to protect the foot against injuries and adverse weather conditions. When choosing shoes, their basic functions often become secondary, giving way to criteria dictated by fashion. Fashionable shoes are not always healthy. Other

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5 D. Kusz, T. Bienek, J. Cholewiński, Ł. Cieliński, K. Czeladzka-Krerowicz, S. Dudko, M. Nowak, P. Wojciechowski, (2009), *Kompendium ortopedii*, Warszawa.

6 Ibidem.

7 W. Dega, K. Milanowska, (1993), *Rehabilitacja medyczna*, Warszawa.

8 M. Borkowska, I. Gelleta-Mac, (2009), *Wady postawy i stóp u dzieci*, Wydawnictwo PZWL, Warszawa.

factors causing distortions may also be diseases (tuberculosis, poliomyelitis, diabetes, rheumatoid arthritis, etc.). The type of occupation and work performed also influences the formation of distortions in adults. Both standing work and continuous performance of the same activities (e.g. walking) can cause distortions. Gender may also be a determining factor in the formation of the defect: the weaker structure of the female foot exposes it to more frequent occurrence of flat valgus foot and hallux valgus.

The acquired defects of feet include, among others:

- flat and flat – valgus foot,
- transversely flat foot (transverse flatfoot, forefoot overload syndrome),
- hollow foot,
- hallux valgus,
- “tailor’s bone”,
- stiff toe,
- deformities of fingers II–V,
- inflammation of the sesamoids,
- metatarsalgia, including Morton’s disease,
- heel spur (inflammation of the plantar fasciitis),
- diseases of the Achilles tendon,
- injuries of the ankle joint,
- calluses and corns,
- Athlete’s foot,
- ingrown nails.

4.2.1. Clubfoot (congenital)

Clubfoot has a characteristic shape and its recognition is easy. However, this defect may have a diverse etiological background, which has a significant impact on the choice of a treatment method. There are several hypotheses regarding the aetiologia of the distortion. The oldest of them is the hypothesis postulating the participation of mechanical factors in the formation of the defect (intrauterine compartment, incorrect position of the foot during foetal growth of the limb). The neuromyogenic hypothesis considers changes as minor myelodysplastic disorders within the spinal cord to be the etiological factors of the defect, which causes a difference in the innervation of the foot and lower leg muscles. Recent reports in the related literature suggest the involvement of genetic factors and a complicated way of inheriting the defect.

The image of the defect includes three elements: tarsal equine, tarsal supination and forefoot, forefoot adduction and foot cavities.

There are various degrees of severity of the defect, from small, fully corrective the so-called “soft” clubfoot distortions to non-corrective “hard” with full and intensified individual elements of the defect. For the purpose of treatment planning, its conduct and comparison of treatment results, it is extremely important to assess and determine the severity of the defect.

It is assumed that the anatomopathological essence of the clubfoot deformity is the displacement of the navicular, calcaneus and cuboid around the talus. As a result of the above, the talus undergoes external rotation, dislocation within the talonavicular joint and internal rotation of the calcaneus. Secondary changes occur in the muscles: contracture of the triceps calf muscle, tibialis posterior, flexor digitorum longus, and hallux. The above-mentioned changes are accompanied by the contracture of joint capsules and ligaments from the posterior and medial side of the foot.

The general rule is to start treatment as soon as possible after birth. It includes conservative treatment involving the application of corrective plaster casts. In the case of a mild defect, this treatment usually leads to full correction. However, in the case of the majority of children, conservative treatment is an introduction to surgical treatment, which is carried out between 2 and 10 months of age. After surgical treatment, immobilisation of the foot in plaster casts lasts about 1 to 3 months. After this period, various types of orthoses are used.

The goal of the clubfoot treatment is to restore the correct anatomical relationship and reconstruct the correct shape of the foot so that the patient can wear standard footwear. In many cases such as the existence of the so-called residual deformations, numerous hypertrophic scars, foot pain, especially after multiple recurrences of the defect, it is extremely important to choose the right insoles or make orthopaedic footwear.

As mentioned, the aetiology of the defect can be diverse. Depending on the causes of the defect, the following types of club feet are distinguished (Table 4.1.).

Table 4.1. Clubfoot Types

Lp.	Type of defect	Cause	Treatment	Risk of recurrence
1	**Habitual**	Incorrect positioning of the foot in the uterine cavity	Use corrective immobilisation or appropriate footwear as early as possible.	Extremely low
2	**Idiopathic**	Most often as an isolated defect. Sometimes it coexists with torticollis or congenital hip dysplasia.	From birth – initially plaster casts, and then surgical treatment with plaster casts	Up to 6 years
3	**Teratogenic**	Neuromuscular diseases in foetal life	Neuromuscular disease in foetal life	Frequent relapses

Source: own elaboration.

Figure 4.3. Clubfoot
Source: https://fizjo-gabinet.pl/stopa-konsko-szpotawa-fizjoterapia/ (accessed: 12.12.2023).

4.2.2. Adjusted foot (congenital)

This is a relatively common defect involving the adduction of the forefoot of varied degrees of severity. It consists in adducting the forefoot, or rather the first radius of the foot, in relation to the rest of the foot at the level of the Lisfranc joint. The foot resembles the shape of a kidney. The rest of the foot is normal, although sometimes there is a valgus position of the heel and dorsiflexion of the foot is normal. The lesion is often bilateral but usually asymmetric. Most likely, it is the result of improper positioning of the feet in the uterus. Spontaneous subsiding of the defect in the case of 85% of children is the proof of such aetiology. In milder cases, in the early childhood, it may go undiagnosed and only the child's gait with turning the eet inwards causes the parents to report to the doctor. The easiest way to recognize this defect is when the child is lying on his stomach with bent knees. In this case, the twisting of the forefoot towards the inside is clearly visible at the level of the Lisfranc tarsi-metatarsal joints. The step is set correctly. Forefoot adduction is corrected passively. The foot has full functional capacity and its movements are free.

In the case of rigid adduction of the forefoot, serial plaster casts are used. Only severe, non-corrective deformities require surgical treatment.

Figure 4.4. Adducted Foot
Source: https://eskulap.olsztyn.pl/leczona-choroba/wrodzona-stopa-przywiedziona/ (accessed: 12.12.2023).

4.2.3. Congenital flat foot

Congenital flat-valgus foot is a rare but difficult-to-treat defect, resulting in a relatively large number of poor treatment results. It occurs on one or both sides. It is characterised by an abolition or even a curvaceous bend of the longitudinal arch of the foot, the lowest point of which on the sole is formed by the head of the talus, dislocation towards the dorsal side in the talo-navicular joint and equine setting of the calcaneus, caused by the contracture of the triceps calf muscle. This deformation is mainly a problem of cosmetic disfigurement and conflict with ready-made footwear, which is quickly deformed when walking. In childhood, this defect is painless, hardly impairing the walking function, while in adulthood, pain occurs due to degenerative changes in the joints of the foot or skin calluses appearing on the most protruding points on the plantar side. The treatment of choice in infancy is surgery followed by plaster casts, insoles and appropriate orthopaedic footwear.

4.2.4. Heel foot

Congenital calcaneal foot – is a mild deformity that is easily subjected to passive correction and does not cause major problems in the treatment of. The foot is set in dorsiflexion and usually valgus (i.e. in pronation). The deformity is caused by the incorrect positioning of the foetus in the mother's womb (the so-called habitual deformity). Treatment consists of manipulative exercises of the foot (i.e. correcting its position) or applying corrective casts for a short period of time.

Figure 4.5. Heel foot
Source: https://www.google.com/url?sa=i&url=https%3A%2F%2Fwww.bryk.pl%2Fwypracowania%2Fpozostale%2Frehabilitacja%2F18677-wady-wrodzone-w-obrebie-kkd.html&psig=AOvVaw2Xf4oLqogGLEck5vXaxC_R&ust=1681543402919000&source=images&cd=vfe&ved=0CA4QjRxqFwoTCKjXzvfqqP4CFQAAAAAdAAAAABAK (accessed: 12.12.2023).

4.2.5. Congenital extension of the knee joint

This defect is characterised by limited flexion of the knee up to hyperextension of the joint and dislocation of the tibia onto the anterior surface of the femur. Treatment depends on age and degree of deformation. In new-borns, Pavlik Harness is used in order to force knee flexion and plaster casts to correct the position of the joint ends. The surgical method consists in lengthening the quadriceps muscle.[9]

4.3. Podiatry screening of children at preschool and school age

4.3.1. Research method

Children's feet were examined in kindergartens, primary schools, and sports clubs mainly in the City of Cracow.

4.3.2. 3D scanner-based screening

In the course of the screening, the child placed the examined foot inside the scanner, and the other on special stands located on the right and left side of the scanner, respectively. During the scanning process that lasted about 30 seconds, the child stood motionless in an upright position, evenly loading the lower limbs. The device scanned the foot body and the plantar side of the foot, while making anthropometric measurements in accordance with the given algorithm.

The scan files were saved in the .scm format allowing for measurements of the foot body, and in the .stl format providing for reconstruction in 3D programs in order to modify the image later (the so-called point cloud).

Occasionally, multiple foot scans were required due to an incorrect image generated by the computer.

After performing the correct foot scan and measurement, test reports were generated.

9 D. Kusz, T. Bienek, J. Cholewiński, Ł. Cieliński, K. Czeladzka-Krerowicz, S. Dudko, M. Nowak, P. Wojciechowski, (2009), *Kompendium ortopedii…*

Figure 4.6. Placing the foot in the 3D scanner
Source: own elaboration.

4.3.3. Anthropometric measurements of the feet

To assess the dimensions of the feet, in addition to the 3D scanner, the traditional technique of anthropometric measurements was also used by means of a diameter compass, a shoe measuring tape and an altimeter.

During the examination, the child stood with the feet slightly apart, evenly loading the feet.

After the tests, the obtained results were converted into the length and width dimensions of the footwear.

The test procedure is shown in the pictures below:

Figure 4.7. Measuring the length of the foot by means of a diameter compass
Source: own elaboration.

Figure 4.8. Measuring the width of the forefoot by means of a diameter compass
Source: own elaboration.

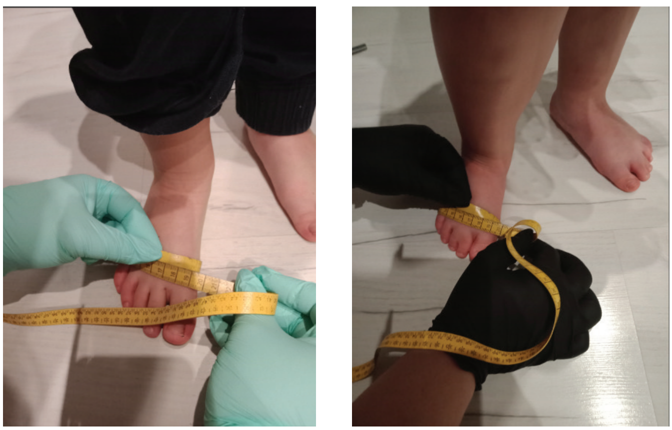

Figure 4.9. Measuring the circumference of the forefoot by means of a shoe measuring tape
Source: own elaboration.

The obtained results were entered into a database and subjected to statistical analyses.

4.3.4. Orthopaedic assessment

The next stage of the preliminary examination was the orthopaedic assessment of the health condition of the children's lower limbs. This is a key element of research in terms of monitoring foot deformation changes in the developmental age.

In accordance with the developed procedure, in the subsequent stages of the examination, the position of the knees, forefoot, toes (during the examination of the patient from the front) and the position of the tarsus during the examination of the patient from the back were assessed.

During the assessment, attention was also paid to deformities of fingers 2–5, ingrown nails and skin changes. In the next stage, the longitudinal arch of the foot was assessed. The results of the assessment were recorded in the patient's examination card. Photographic documentation of the examinations of selected patients is presented below.

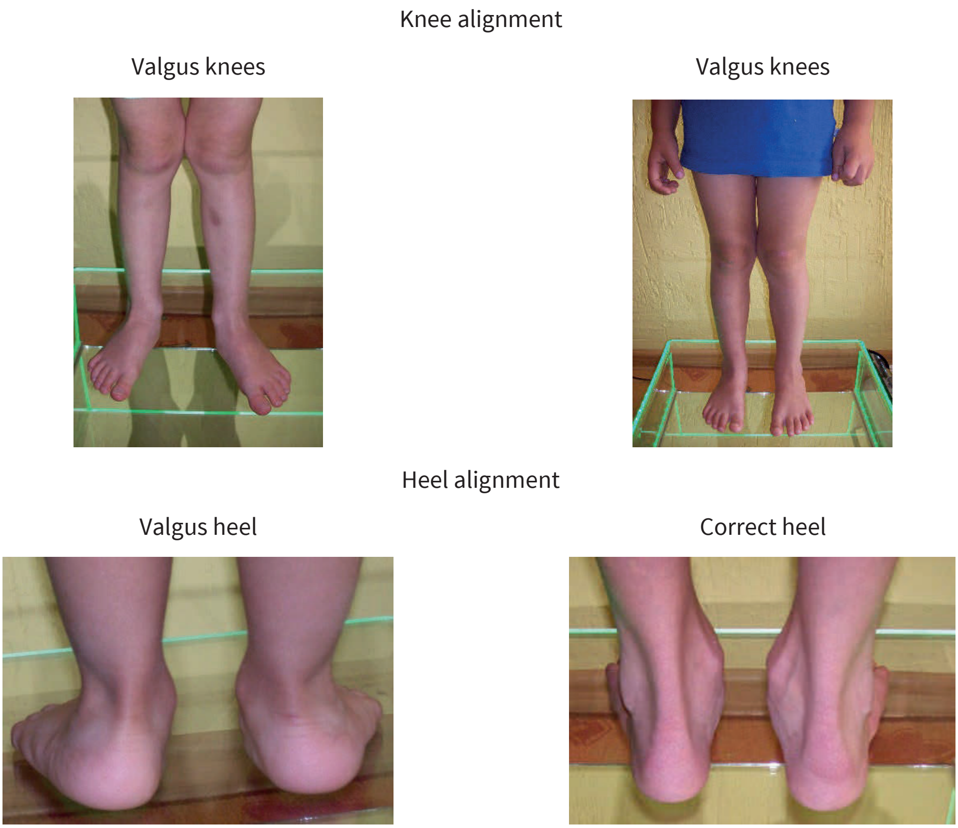

Figure 4.10. Evaluation of knee and tarsus alignment in selected patients
Source: own elaboration.

Figure 4.11. Sample images of the plantar side of the foot visible on the podoscope
Source: own elaboration.

The next stage of the examination was the assessment of the child's skin condition. Particular attention was paid to the presence of moles, warts, fungal lesions, ingrown nails or improperly shortened nail plate.

Photographic documentation of selected cases is presented below.

Virus wardon the plantar side of the foot

Birthmark on the dorsal side of the foot

Figure 4.12. Photographic documentation of skin and nail condition assessment
Source: own elaboration.

4.4. Test results and data analysis

4.4.1. 3D scanner-based screening

4.4.1.1. Characteristics of the population

As part of the task, 2,560 foot scans of children aged 3–15 were performed. The children were classified according to age and sex criteria. Table 4.2. presents the number of children in respective age groups, taking into account the breakdown by gender.

Table 4.2. The number of children in respective age groups, taking into account the breakdown by gender

Age	Girls	Boys	Totals
1	2	3	4
3	18	22	40
4	22	36	60
5	32	50	82
6	32	60	92
7	84	98	182
8	132	224	356
9	216	238	456

1	2	3	4
10	162	194	356
11	176	118	294
12	120	140	260
13	108	98	206
14	46	82	128
15	14	20	34
Totals	1162	1380	2546

Source: own elaboration.

4.4.1.2. 3D scanner-based screening – results of anthropometric measurements by gender

Below are the results of anthropometric measurements made by means of a 3D scanner. Three basic anthropometric parameters indicating foot length, width and circumference of the forefoot were analysed. The analysis was carried out in age groups, taking into account the division into sex.

Table 4.3. Results of basic anthropometric measurements for girls

Age	Foot length				Forefoot width				Forefoot girth			
	Av.	Min	Max	S.dev	Av.	Min	Max	S.dev	Av.	Min	Max	S.dev
2	135.4	133.4	139.1	2.6	62.4	59.9	65.1	2.1	158.0	156.0	160.2	1.7
3	149.3	136.2	164.7	9.4	62.4	55.6	68.8	3.8	155.4	141.5	168.7	7.5
4	160.7	152.1	174.8	7.0	65.2	60.3	73.3	3.7	163.6	148.8	182.5	9.1
5	166.8	149.9	183.6	8.5	66.5	58.8	72.0	3.8	164.2	146.4	176.8	8.7
6	178.8	164.4	198.4	8.0	71.1	62.7	77.1	3.6	174.1	154.4	191.0	9.0
7	192.0	168.2	221.2	11.1	73.4	64.1	89.4	5.0	181.1	161.5	217.9	12.0
8	199.4	175.3	241.7	11.6	77.2	64.6	88.4	4.9	190.1	159.9	219.0	12.0
9	208.9	174.1	239.8	11.6	80.1	69.8	96.2	4.9	195.7	169.2	229.9	11.4
10	217.7	190.0	246.1	12.4	83.4	68.9	102.6	6.8	204.3	168.5	247.9	15.8
11	226.1	187.7	259.2	13.5	86.5	68.5	103.0	7.1	211.1	168.0	252.1	17.0
12	233.2	205.2	258.8	12.1	89.6	81.1	100.7	4.6	218.1	199.4	249.0	11.1
13	241.1	202.7	260.8	11.7	92.8	78.0	104.5	5.4	225.5	187.2	249.9	11.8
14	238.8	213.1	260.7	11.3	92.5	82.5	105.6	6.3	224.3	199.9	252.1	12.3
15	233.8	225.2	248.5	7.3	89.6	83.7	95.2	3.5	217.2	202.8	230.4	8.2

Source: own elaboration.

As it results from the presented data, periods of acceleration and retardation of growth are observed in the course of ontogenesis within all the examined parameters. Lower values of anthropometric parameters were observed only in the group of 15-year-old girls. Such results are related to the small number in the group of 15-year-old children. However, taking into account the fact that at this age parents have little influence on the child's fashion and preferences regarding shoes, the result should be considered an indicative value.

Table 4.4. Results of basic anthropometric measurements for boys

Age	Foot length				Forefoot width				Forefoot girth			
	Av.	Min	Max	S.dev	Av.	Min	Max	S.dev	Av.	Min	Max	S.dev
2	151.3	132.3	175.2	12.30	64.00	57.9	71.7	4.10	159.2	147.2	177.5	9.20
3	160.6	143.9	180.0	7.90	65.60	57.9	71.3	3.40	161.4	137.7	175.8	9.40
4	172.5	157.4	191.9	7.604	74.86	63.9	166.8	20.47	173.1	158.1	196.5	10.85
5	183.6	155.1	202.9	10.25	74.51	61.8	85.6	5.664	183.3	153.7	210.2	13.80
6	197.1	175.3	234.3	11.45	77.48	68.1	95.8	5.281	189.9	166.8	243.3	13.33
7	203.6	178.5	232.0	11.73	79.76	66.7	91.6	5.199	196.0	165.6	224.0	12.08
8	213.3	185.2	243.6	11.47	82.79	71.5	99.1	5.622	203.5	178.0	241.3	13.48
9	221.1	192.0	259.8	13.64	85.15	74.5	103.6	5.851	209.2	183.1	255.0	14.29
10	228.0	202.5	248.8	10.16	88.92	76.9	104.9	6.161	217.6	189.9	253.7	14.20
11	237.9	209.0	271.2	13.19	92.34	76.2	110.6	6.988	224.3	22.4	270.9	23.71
12	248.8	217.8	275.1	12.76	97.30	85.6	116.2	7.386	235.8	206.7	280.2	17.52
13	254.0	220.1	279.0	13.11	97.89	81.8	109.1	5.954	238.0	199.3	262.4	13.61
14	256.7	242.5	279.5	12.60	97.43	5.954	115.0	12.23	236.7	13.61	275.7	29.36
15	264.5	258.6	276.9	6.64	100.00	90.7	108.3	7.316	244.8	223.7	263.4	16.73

Source: own elaboration.

A similar growth rate of foot parameters is also observed in the population of the surveyed boys. Individual parameters show periods of growth acceleration and its slowdown.

4.4.2. Orthopedic assessment

4.4.2.1. Characteristic of the population

As part of the task, the orthopaedic assessment was performed for 1727 children aged 4–15.

Table 4.5. The number of children in respective age groups, taking into account the breakdown by gender

Age	Girls	Boys	Totals
4	12	15	27
5	10	21	31
6	20	30	50
7	16	32	48
8	70	67	137
9	150	132	282
10	137	151	288
11	137	119	256
12	111	80	191
13	107	89	196
14	23	59	82
15	97	42	139
Totals	890	837	1727

Source: own elaboration.

4.4.2.2. Data analysis

The collected data was subjected to statistical analyses, calculating the percentage share of children with specific deformities. The analyses were performed in age and sex groups.

A tabular summary of the obtained orthopaedic assessment results is presented below.

4.4.2.2.1. Knee alignment

Table 4.6. Knee alignment

Knee alignment [% of girls group]				
Age	**n**	**Varus**	**Correct**	**Valgus**
1	2	3	4	5
4	12	0	33	67
5	10	0	60	40
6	20	0	75	25
7	16	0	94	6
8	70	0	94	6
9	150	0	91	9
10	137	0	96	4

Table 4.6 (cont.)

1	2	3	4	5
11	137	0	91	9
12	111	0	91	9
13	107	1	95	4
14	23	0	91	9
15	97	0	97	3

Source: own elaboration.

As it can be seen from the above data, 67% of girls aged 4 have valgus knees. Valgus declines with age, reaching 40% in 5-year-olds and 25% in 6-year-olds, respectively.

Table 4.7. Knee alignment

Knee alignment [% of boys group]				
Age	**n**	**Varus**	**Correct**	**Valgus**
3	15	0.0	60.0	40.0
4	21	19.0	52.7	47.3
5	30	0.0	83.3	19.6
6	32	0.0	93.8	6.2
7	67	0.0	97.0	3.0
8	132	0.8	93.9	5.3
9	151	1.3	92.1	6.6
10	119	0.0	95.8	4.2
11	80	0.0	96.3	3.4
12	89	2.3	92.1	5.6
13	59	0.0	98.3	1.7
14	42	0.0	97.1	2.9
15	11	0.0	97.1	2.9

Source: own elaboration.

In the case of boys, the phenomenon of physiological knee valgus is also noticeable. The highest percentage share of boys with physiological valgus was noted – similarly to girls – at the age of 4 (47.3%). Amongst girls, varus of the knees at school age is more often the case, which may be caused by more frequent football practice by boys than girls.

According to the stages of shaping the lower limb in the course of ontogenesis, knee valgus is a physiological phenomenon that replaces the earlier physiological varus (positioning of the knees in the case of non-ambulatory children). When you start walking, the lower limbs are loaded with body weight. Then the so-called physiological valgus is observed to reach its maximum between 2 and 4 years of age. By about 6–7 years of age, the knee valgus should decrease, and the lower limbs should be placed in an increasingly correct position.

4.4.2.2.2. Heel alignment

Table 4.8. Heel alignment

Heel alignment [% of girls group]				
Age	**n**	**Varus**	**Correct**	**Valgus**
4	12	0.0	16.7	83.3
5	10	0.0	50.0	50.0
6	20	0.0	60.0	40.0
7	16	0.0	75.0	25.0
8	70	0.0	81.4	18.6
9	150	0.0	80.0	20.0
10	137	0.0	82.2	17.8
11	137	0.0	82.5	17.5
12	111	0.0	82.9	17.1
13	107	0.0	90.1	9.9
14	23	0.0	87.0	13.0
15	97	0.0	97.1	2.9

Source: own elaboration.

As it results from the presented data, there were no cases of clubfoot in the study population. On the other hand, valgus heel position constitutes a higher percentage share of the population in the group of 4-year-old girls (83.3%).

With age the walking posture improves in favour of correct positioning. Among 7-year-old girls, valgus of the tarsus occurs in 25% of them. This proves the disappearance of the physiological valgus of the tarsus, which correlates with the valgus position of the knees.

In the studied group of girls, cases of valgus were noted in every age group – up to 14 years of age but it should be borne in mind that for those over 7 years of age incorrect tarsus setting should already be under the control of an orthopaedist or a physiotherapist.

Table 4.9. Heel alignment

Heel alignment [% of boys group]				
Age	**n**	**Varus**	**Correct**	**Valgus**
3	15	0.0	6.7	93.3
4	21	0.0	19.0	81.0
5	30	0.0	46.7	53.3
6	32	0.0	53.1	46.9
7	67	0.0	55.9	43.6
8	132	0.0	70.1	29.9
9	151	0.0	73.5	26.5
10	119	0.0	73.9	26.1
11	80	0.0	77.5	22.5
12	89	1.1	76.4	22.5
13	59	0.0	79.7	20.3
14	42	0.0	97.1	2.9
15	11	0.0	97.1	2.9

Source: own elaboration.

In the population of boys, a similar trend of changes in the position of the tarsus is observed, which confirms the direction of physiological changes during the development of the lower limbs.

Physiological valgus remains at a high level until about 6–7 years of age (and therefore slightly longer than in the case of girls), and moreover, the percentage share of boys tested in a given age-sex group is higher as compared to the corresponding group of girls. However, this conclusion should be treated with caution because the number of children in particular age and sex groups is different.

4.4.2.2.3. Forefoot alignment

Table 4.10. Forefoot alignment

Forefoot alignment [% of girls group]			
Age	**n**	**Correct**	**Adducted**
1	2	3	4
4	12	100.0	0.0
5	10	100.0	0.0
6	20	100.0	0.0
7	16	100.0	0.0
8	70	100.0	0.0

1	2	3	4
9	150	100.0	0.0
10	137	99.3	0.7
11	137	100.0	0.0
12	111	100.0	0.0
13	107	96.3	3.7
14	23	100.0	0.0
15	97	97.1	2.9

Source: own elaboration.

In the studied population of girls, in most age and sex groups, forefoot adduction was not observed. Cases of deformity were recorded in a maximum of 3.7% at the age of 12, which can be considered insignificant due to the size of the groups. On the basis of the gathered data, it is difficult to unambiguously determine the periods of changes taking place.

Table 4.11. Forefoot alignment

Forefoot alignment [% of boys group]			
Age	**n**	**Correct**	**Adducted**
3	15	93.3	6.7
4	21	100.0	0.0
5	30	100.0	0.0
6	32	100.0	0.0
7	67	98.5	1.5
8	132	99.2	0.8
9	151	99.3	0.7
10	119	98.3	1.7
11	80	97.5	2.5
12	89	98.9	1.1
13	59	100.0	0.0
14	42	97.0	3.0
15	11	97.1	2.9

Source: own elaboration.

A similar phenomenon is observed in the population of boys, although here in the case of 3-year-olds as many as 6.7% of boys had adduction of the foot in the Lisfranc joint.

4.4.2.2.4. Positioning the first toe andothers toes

Table 4.12. Positioning the first toe

Positioning the first toe [% of girls group]			
Age	**n**	**Correct**	**Valgus**
4	12	100.0	0.0
5	10	100.0	0.0
6	20	95.0	5.0
7	16	100.0	0.0
8	70	98.6	1.4
9	150	98.6	1.4
10	137	95.6	4.4
11	137	97.8	2.3
12	111	96.4	3.6
13	102	94.1	5.9
14	23	95.6	4.4
15	97	97.1	2.9

Source: own elaboration.

Table 4.13. Positioning the first toe

Positioning the first toe [% of boys group]			
Age	**n**	**Correct**	**Valgus**
3	15	100.0	0.0
4	21	100.0	0.0
5	30	100.0	0.0
6	32	100.0	0.0
7	67	100.0	0.0
8	132	98.5	1.5
9	151	100.0	0.0
10	119	98.3	1.7
11	80	98.8	1.2
12	89	100.0	0.0
13	59	100.0	0.0
14	42	97.1	2.9
15	11	97.1	2.9

Source: own elaboration.

Deformities of the other fingers were very rare. They concerned mainly the 2nd toe that was deformed due to wearing shoes that were too short (especially the Greek-type foot, in which the 2nd toe is longer). The varus alignment of the fifth toe, that had until recently been considered a deformity, has been observed frequently, but is now recognised as an evolutionary change.

4.4.2.2.5. Shape of the longitudinal arch

Table 4.14. Shape of the longitudinal arch

Shape of the longitudinal arch [% of girls group]					
Age	**n**	**Correct**	**Low**	**Flatfoot**	**Hollow**
4	12	0.0	75.0	25.0	0.0
5	10	30.0	60.0	10.0	0.0
6	20	35.0	50.0	15.0	0.0
7	16	62.5	25.0	12.5	0.0
8	70	77.1	21.4	1.5	0.0
9	150	82.7	16.7	0.6	0.0
10	137	82.5	12.4	5.1	0.0
11	137	81.8	17.5	0.7	0.0
12	111	78.4	16.2	5.4	0.0
13	99	84.8	10.1	5.1	0.0
14	23	82.6	8.7	8.7	0.0
15	97	97.1	2.9	0.0	0.0

Source: own elaboration.

Table 4.15. Shape of the longitudinal arch

Shape of the longitudinal arch [% of boys group]					
Age	**n**	**Correct**	**Low**	**Flatfoot**	**Hollow**
1	2	3	4	5	6
3	15	13.3	60.0	26.7	0.0
4	21	19.0	57.1	23.9	0.0
5	30	40.0	40.0	20.0	0.0
6	32	62.5	34.4	3.1	0.0
7	67	62.7	23.9	13.4	0.0
8	132	64.4	27.3	8.3	0.0
9	151	66.2	28.5	5.3	0.0
10	119	78.2	16.8	5.0	0.0

Table 4.15 (cont.)

1	2	3	4	5	6
11	80	78.8	15.0	6.2	0.0
12	89	85.4	13.5	1.12	0.0
13	59	88.1	10.2	1.7	0.0
14	42	97.1	2.9	0.0	0.0
15	11	97.1	2.9	0.0	0.0

Source: own elaboration.

The arch of the foot develops until about 6–7 years of age. As mentioned in the introduction, we initially observe the phenomenon of physiological flat feet, which, according to the related literature, disappears at school age (more quickly in the case of girls).

The presented data analysis shows that among girls up to about 6–7 years of age we observe a lowering of the longitudinal arch with a tendency to flat feet. In the case of 7-year-old girls, 62.5% of the study population have properly arched feet. Among older girls (9–14 years), about 18% have low-arched feet or flat feet.

In the studied population of boys, the dynamics of changes in the morphology of the arch are similar, however, feet with a physiological lowering of the longitudinal arch and physiologically flat feet are observed in a larger group of boys than in girls (given the analysis of the corresponding age groups).

The obtained research results are confirmed by the related literature.

4.5. Principles of selection and assessment of children's shoes

4.5.1. Adjusting the shoes to the length of the foot

Wearing shoes that are too short is one of the causes of acquired foot defects. Shoes that are too small deform children's feet, aggravate ailments in adults, and are simply uncomfortable. On the other hand, shoes that are too big make it difficult to walk and force you to move unnaturally. So, a seemingly simple thing has a significant impact on the health of our legs and thus on our well-being. This issue is more complicated in the case of footwear for children but also footwear for adults plays an important role. Of course, one can say that adults are "adults" and decide for themselves and also decide for their children, namely what shoes they and their children wear. However, a part of the responsibility falls on the manufacturers of the lasts and shoe manufacturers.

When discussing this problem, it is necessary to pay attention to several aspects, namely:

- the influence of the method of measurement on determining the length of the foot;
- foot length growth rate;
- change in the length of the foot while walking;
- difference in foot dimensions under load;
- foot length with different heel heights.

It is obvious that the dimensions of the feet increase with age. In the case of children, they grow about 10 mm in length per year but there are periods of faster and slower growth, different among girls and boys. Significant individual differences are also observed. For most girls, the length of the foot reaches its "adult" dimension by the age of 13, while for boys it takes a little longer – until the age of 16–18. Then we observe that the feet become wider and thicker.

The highest growth rate is observed between 5 and 6 years of age, both in boys and girls, in the case of whom this rate clearly decreases after the age of 11. Due to the much smaller number of children measured in the Cracow and Nowy Sącz studies,[10] the distribution of values is uneven but it is clear that the growth rates over the period under consideration are very high.

Table 4.16. Foot length increase (mm) in various children populations

Research	Sex	Age									
		3,4	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**
Poland	**Boys**	9,7	7,7	10	9	7,9	8,4	7,7	7,8	7,4	9,6
	Girls	8,8	9,9	9,1	9,7	7,5	8,9	7,3	8,2	6,2	5,1
N. Sącz	**Boys**	7,4	10,5	9,8	6,9	9,1	9,8				
	Girls	10,6	8,1	10,5	6,1	9,3	7,2				
Cracow	**Boys**	11,2	7,2	9,9	10,2	4,1	16,4	6,4	9,8	6,9	12,7
	Girls	7,8	11,9	6,7	9,4	10,7	10,8	2,4	10,8	5,7	4,4

Source: own elaboration.

10 A. Malinowski, T. Lewicki, Z. Śniegowski, (1975), *Antropometryczne pomiary stóp i możliwości ich zastosowania w przemyśle ortopedycznych*, „Przegląd techniki ortopedycznej i rehabilitacyjnej", vol. 3.

Table 4.17. Foot length increase (mm) in Cracow children (semi-longitudinal examinations)

I group								
Avarage age Year.Month	Increase							
	Boys	Girls						
7.7								
8.3	1.8	1.6						
8.8	2.2	2.8	II group					
9.3	6.6	5.5	Avarage age Year.Month	Increase				
9.8	4.4	4.5		Boys	girls			
10.2	4.8	5.7	10.30					
10.7	3.9	3.3	10.11	2.0	2.4			
11.2	4.4	4.2	11.50	4.4	3.0	III group		
11.7	4.0	3.0	12.00	3.2	4,4	Avarage age Year.Month	Increase	
			12.50	5.2	3.5		boys	girls
			13.10	6.1	1.8	13.3		
			13.50	3.3	1.6	13.1	3.0	0.0
			13.11	5.1	1.5	14.4	2.2	0.0
			14.30	0.9	0.0	15.0	4.7	0,7
						15.2	1.0	0.8
						15.1	3.5	0.3
						16.5	18.4	0.0

Source: own elaboration.

Łukasiewicz-ŁIT also measured the feet of the same children attending one of the schools in Cracow, every six months. Those studies were commenced in three age groups – children aged 7, 10 and 13 (those were semi-longitudinal studies). Table 4.17. presents the results of those studies. Analysing the data contained in it, it should be noted that in boys, throughout the period at issue, the increments are about 5 mm – that is half a number in the metric sizing system and almost one number in French (Continental) sizing system, i.e. the sizing according to which almost all footwear models in Poland are made.

"Change in foot length" while walking

In addition to the increase in the length of the foot with age, the changes in the shape of the foot during walking should also be taken into account when choosing footwear. Observed in slow motion, can the image of body weight transfer during walking be presented in the following stages: the weight rests on the heel, it is transferred to the outer edge of the foot in the metatarsal area, it is transferred to the metatarsal heads (just behind the toes towards the heel), followed by a bounce from the toe to the next step. In this stage, due to the direction of foot movement and the energy with which the foot moves, we observe the movement of the entire foot towards the tip of the shoe. How big is this shift? Łukasiewicz-ŁIT carried out tests by means of making a foot print in static (standing) and dynamic (walking) conditions, using a set for mapping foot pressure called Ortho-track by Otto Bock. The differences between the two measurements ranged from 8 to 16 mm.

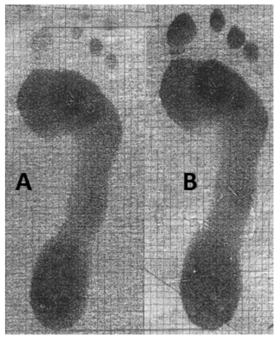

Figure 4.13. a) Static test; b) Dynamic test
Source: own elaboration.

This difference probably results not only from the movement of the foot in the shoe while walking, but also from the change in the shape of the foot under the influence of load, therefore it must be taken into account when selecting and making footwear.

Based on the research results elaborated upon above, regarding the correct adjustment of the length of shoes to the length of the user's feet, it must be remembered that the following factors must be taken into account when making or selecting footwear:

- in the case of footwear intended for children, the increase in foot length over a certain period of time should be taken into account – the length of the foot increases by 10 mm on average per year;
- due to the movement of the foot in the shoe, the shoe must be longer than the foot when walking. The Polish standard regarding last dimensions recommends that the foot length allowance, called the "functional allowance", should be from 7 to 5% of the foot length (higher percentage for smaller feet).

In order to determine the size of the foot, one can use professional rulers (Figure 4.15.) on which the foot size is automatically converted into a size number. As part of the Project, a leaflet was developed to provide information on the rules of footwear selection as well as a measuring device (Figure 4.18.).

The measurement can also be made using measuring instruments such as a calliper or a diameter compass. However, it should always be remembered that regardless of the measurement method, the data obtained is only auxiliary, and the degree of foot fit should be verified in the footwear. In this case, it is recommended to use removable insoles, that, after having been taken out of the footwear and having placed the foot into them, show how much allowance is left in the footwear. It is also useful for the purpose of an ongoing control during the use of footwear, which prevents the use of footwear that the child has already "grown out of".

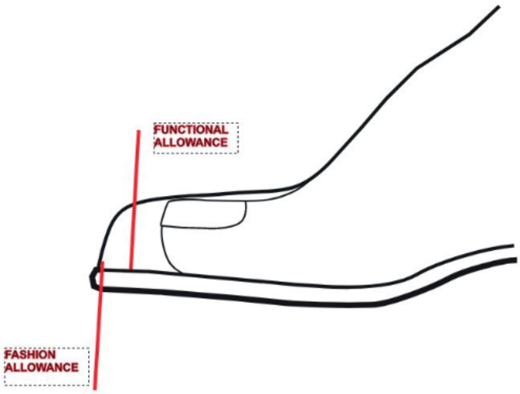

Figure 4.14. Foot length allowances
Author: Tetiana Paruzel.

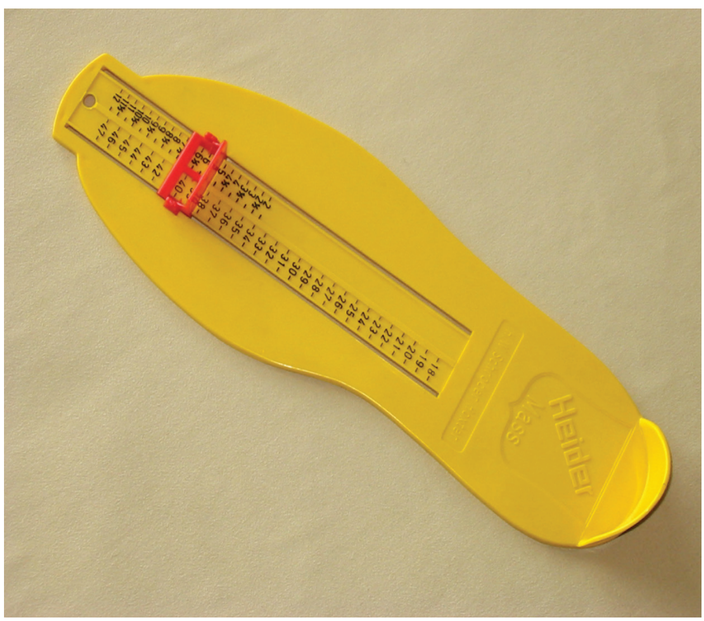

Figure 4.15. A specialist measuring instrument for determining the size of the foot (foot length metre)
Source: own elaboration.

Figure 4.16. The leaflet with a measuring tape
Source: own elaboration.

Figure 4.17. The leaflet with a measuring tape
Source: own elaboration.

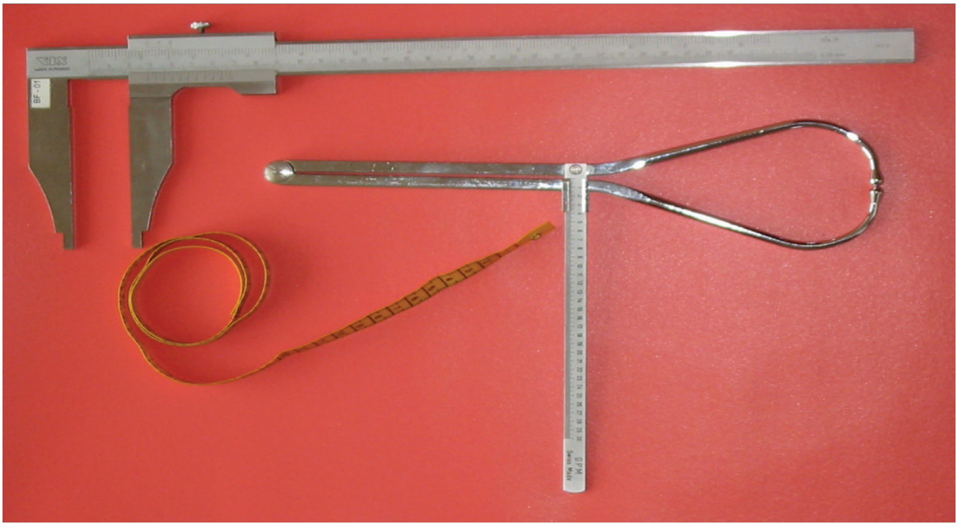

Figure 4.18. A Calliper, diameter compass, measuring tape
Source: own elaboration.

4.6. Evaluation of children's shoes

The basic criterion for evaluating the correct children's footwear is the degree of protection against deformations and other foot diseases (mycoses, allergies, ingrown toenails) as followed by durability and aesthetic qualities.

The correct children's footwear must first of all:

- take into account the shape, dimensions and activities of the feet, and thus ensure free positioning of the fingers and proper adjustment to the shape and width of the feet;
- protect against the adverse effects of a hard substrate and protect against external factors (cold, moisture, sharp elements);
- ensure an appropriate microclimate inside the footwear by securing the appropriate parameters of temperature and humidity inside the footwear, that do not create conditions for excessive growth of fungi and bacteria.

When evaluating the children's footwear and determining their suitability for use by children, the following should be considered:

- last desing,
- selection of raw materials,
- shoe design.

4.6.1. Control of the last dimensions and shape

The last is a geometric form of the foot, that is also a manufacturing item. The last design is closely related to the type of footwear for which the last is intended. In turn, the dimensions of the last and its structure determine the dimensions of the inside of the footwear, being responsible for the degree of fitting the footwear to the foot.

Figure 4.19. Children's lasts
Source: own elaboration.

Since the last is a reflection of the human foot, it is divided into 4 basic components: a heel, metatarsal, forepart and toetip. The most distal part of the last, that is the toetip, may be subject to the greatest modifications in accordance with new fashion trends. This is where the so-called fashion allowance is taken into account, which can be small in the case of wide tips or very large in the case of highly elongated, pointed tips (extremely elongated tips of lasts had a 6-centimetre fashion allowance).

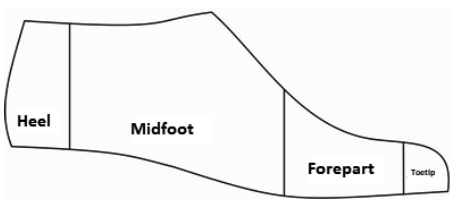

Figure 4.20. The last components
Source: own elaboration.

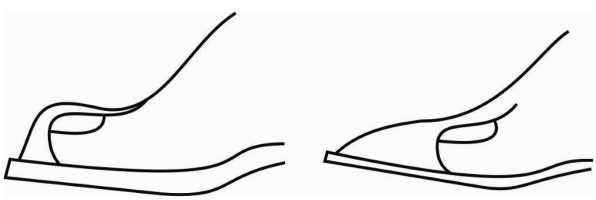

Figure 4.21. Allowances in footwear with different toe shapes
Source: own elaboration.

In the last, we distinguish specific places related to the plastic structure of the last and basic structural elements.

Depending on the purpose, we distinguish:

Low shoe lasts – the characteristic feature of those lasts is the height of the heel and the shape of the back arch of the heel. Lasts are intended for manufacturing shoes with a low (or medium) heel. The correct height of the boot quarter should be marked on the last. The posterior heel arch adduction is relatively slight. The upper arch shaped on this last must not compress the Achilles tendon;

Ankle Boot lasts – the characteristic feature of those lasts is the height of the step and the shape of the rear arch of the heel. That last is intended for manufacturing low-heeled and high-top shoes. The rear part is higher as compared to the last intended for manufacturing low shoes. The rear arch of the heel is abducted, i.e. its upper part deviates slightly backwards;

Sandal lasts – the characteristic of those lasts is the width of the base of the last. It is generally assumed that in lasts intended for manufacturing shoes with an open heel, the width of the footbed in the heel should be 2 mm wider, and in the case of shoes with an open toe, the width of the footbed in the forepart should be 2 mm wider. In those lasts, the total allowance should be 5 mm. The shape of the heel arch is adducted, and in addition the heel can be bulged within the last's base.

Children's feet are especially demanding. It is susceptible to all kinds of pressure, the "effect" of which may be acquired deformities of the feet. Shoes intended for children must therefore have high and wide foreparts. The dimensions of the correct lasts intended for manufacturing the footwear for children are set out in the standard "Footwear for children under 15. Material and construction requirements for lasts and footwear and test methods (PN-O-91015)".

The dimensions determining the shape of the tip are:

1. First toe angle (α)
2. Fifth toe angle (β)
3. Toetip height.

The following parameters should be used for individual size groups:

Table 4.18. Basic parameters of lasts for children's shoes

Age group	**1**		**2**	**3**	**4**	**5**	**6**
Parameter	**10**	**13**	**16**	**18½**	**21**	**23½**	**24**
α angle	92°	91°	89°	89°	87°	84°	87°
β angle	90°	89°	87°	87°	86°	83°	86°
Toetip height, not less than:	15	16	17	18	19	20	21

Source: PN-O-91015:2000 Obuwie dla dzieci do lat 15 – Wymagania materiałowe i konstrukcyjne kopyt i obuwia oraz metody badań.

In order to control the dimensions and shape of the base (bottom) of the last, special control templates can be used. They are applied to the last bedding to check that the bedding "fits" on the last.

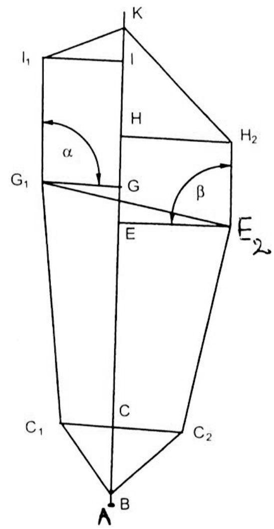

Figure 4.22. Control template for base of the last for children's shoes
Source: own elaboration.

Furthermore, the width of the last must be determined by measuring the length and circumference of the last and then comparing it with the data set out in the standard. The following are used to control the dimensions and shapes of the last: shoemaker's measuring tape, calliper.

Control measurements include:
- Length of the base of the last
- Forepart circumference
- Heel height
- Toetip lift
- Toetip height
- Heel height

The total length of the base of the last – measured after the so-called "wave", i.e. along the longitudinal axis of the last from the starting point of the bedding B, taking into account the curvature of the lower plane of the last.

Forepart circumference – wrap the last with a measuring tape so that it passes through points W1 and W2, W3 (markers on the last). In the absence of markers, apply the control template to the base of the last and, according to it, mark point E2 on the last, and then draw a line from this point perpendicular to the longitudinal axis of the last and mark point E1.

Figure 4.23. Method of measuring the length of the base of the last
Source: own elaboration.

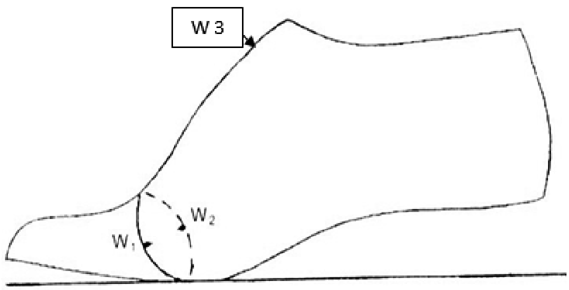

Figure 4.24. Method of measuring the circumference of the forepart
Source: own elaboration.

4.6.2. Verification of footwear design

When assessing the correctness of the performance of children's shoes, the following should be taken into account:

Connections of the upper elements – they should avoid the area of the big toe joint and the fifth toe. The location of those points should be determined in accordance with the "Foot Parameters Grid". Joining the elements stiffens the upper, which may compress and rub the foot.

Height and shape of the heel – the height should not exceed 0–20 mm for younger children, and for girls with feet from 22 to 25 cm–35 mm. In moulded soles, the actual heel height is the difference between the thickness of the sole in the heel and at the thinnest point in the forefoot area.

Easy to put on shoes – the design that facilitates putting on shoes, such as lacing, Velcro fastening, fastening straps – the farther towards the toe the lacing or fastening reaches, the easier it is to put on shoes (Figure 4.25.). Zippers in booties and boots should be sewn diagonally 15–20 mm from the edge of the sole. The diagonal sewing of the zipper makes it easier to put it on.

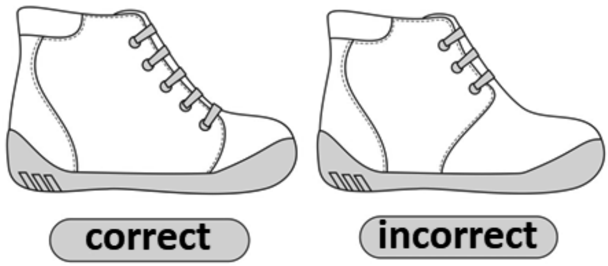

Figure 4.25. Ankle boots with correct and incorrect lacing
Source: own elaboration.

Soft upper materials – uppers of footwear should be made of soft materials, easily adapting to the shape and dimensions of feet;

Upper edges of the uppers – properly finished so that they do not have sharp edges and do not rub feet during use. Indicated finishes, e.g. by wrapping, binding or by using the so-called "shock absorbers" in the upper part of the upper and on the tongue in the form of collars filled with foam;

Figure 4.26. The upper edge of the upper finished with a soft collar
Source: own elaboration.

Lace ends – in shoes for small children, the ends of the laces should be sunk or knotted. Metal or plastic tips are hazardous because a child can swallow them;

Decorative and functional elements – such as discs, buckles, hooks, ornaments, buckles must not have sharp edges and must be fixed in such a way that a small child cannot tear it off and swallow it or put it, for example, into the nose;

Sole texture – anti-slip elements of various heights and shapes, particularly important in winter footwear, but also important in everyday and home footwear, especially for children starting to walk at preschool age. Smooth, slippery soles cause injuries;

Thickness of the soles – thinner soles for everyday and home footwear (optimal thickness of about 4 mm) and for winter shoes to protect against the cold. Thicker soles are recommended to be minimum 6 mm in width. Sole thickness is measured with a thickness gauge or calliper at the midpoint of the forefoot. When assessing the thickness of the sole, it should be remembered that the stiffness of the sole increases with the thickness of the sole, which is not recommendable;

Weight of outsoles – in order to reduce the weight of shoes in moulded soles, various types of relief should be used: holes, grids, etc. (Figure 4.27.);

Figure 4.27. Relief grid in the sole for children's shoes
Source: own elaboration.

Flexibility – a highly flexible sole that bends easily (using little force) at the metatarsophalangeal joints, which makes it easier to roll the foot while walking. In the case of winter footwear, in which, due to the need to use thick soles to protect against the cold and with a deep tread, the footwear may be less flexible. However, in this case, the sole should be profiled in such a way that it facilitates the foot roll without the need to bend the sole (the soles have an arch shaped profile).

The key element in the assessment of children's footwear is the assessment of the inside of the footwear – unevenness and thickening inside the footwear, which may pinch, are unacceptable, and even hurt children's feet. Particular attention should be paid to the sensitive areas of the feet. Sensitive places of the foot are anatomical areas that are particularly exposed to excessive pressure and overload, and are prone to disease and painful deformations:

- the metatarsophalangeal joint of the big toe
- the metatarsophalangeal joint of the fifth toe
- the highest raise point
- the place where the foot passes in the lower leg (joint)
- medial ankle
- lateral ankle
- the rear arch of the heel (around the Achilles tendon).

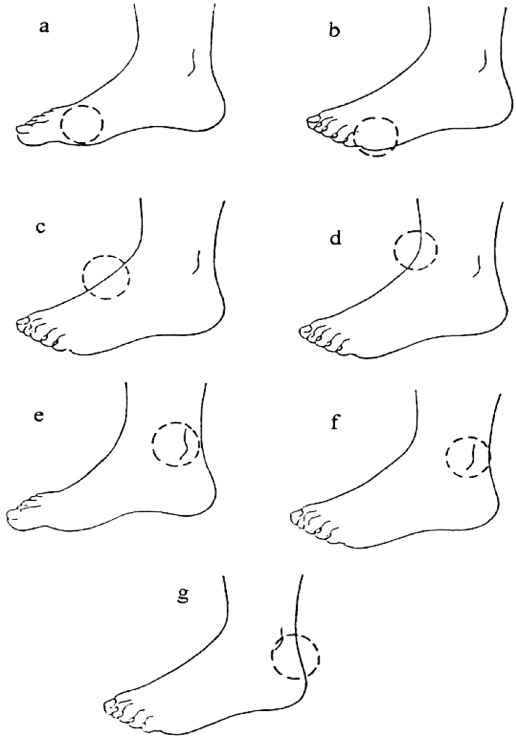

Figure 4.28. Sensitive places of the foot
Source: own elaboration.

The inspection should include:

- joining materials – there must be no thick seams connecting several layers of materials that may hurt the feet;
- the method of attaching small elements – various types of discs, rivets, eyelets, hooks, ornaments should be flattened and fastened in such a way that they do not hurt the foot;
- technological defects – wrinkling of linings, linings, glue residues, embossing of the sole material, sharp ends of threads, nails, clips remaining after attaching the insole to the last, etc.;
- footwear reinforcement elements:

Toe cap – if used in footwear, it must be thinned to "disappear" towards the back of the foot. The length of the toecap should not exceed the bending line of the foot. Poorly thinned and too long toecap can compress the foot in the place where the footwear bends during use. It will also affect negatively the aesthetics of top of the shoes;

Counter – properly developed and formed, it must be consistent with the shape of the heel of the last and elastic enough not to be deformed (not deformed) under the pressure of the foot. The length of the tab wings – in shoes made with a glued system, it should be 2/5 of the length of the last bedding.

Linings – an element in direct contact with the foot, that should be characterised by good hygienic properties. The linings should be glued pointwise so that the adhesive layer does not reduce the hygienic features. It is advisable to use replaceable insoles, especially in winter and rain boots, that are easily removed from the shoes and can be dried, washed or disinfected. Such linings should be additionally stiffened, for instance, glued with cardboard;

Innersoles – have a large impact on the flexibility of footwear. The excessive thickness of the material used for the insoles increases the stiffness of the entire bottom system. It is advisable to use:

- two-part innersoles: the rear part is rigid, the front part is soft;
- innersoles cut in the front part (in the area of metatarsophalangeal joints);
- innersoles sewn in from fabric double-plywood or needled non-woven fabric in footwear made with a direct injection system.

Heel caps – if they consist of two parts, they cannot be connected with a seam that will rub the foot. The leather heel counter should be sewn with the fleshy side to the foot to prevent the foot from slipping out of the footwear, and in insulated footwear to additionally protect against abrasion of the insulating fabric.